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OSCILLATION-TYPE AIR COMPRESSION APPARATUS

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[Scope of Patent Claims]

1. An oscillation-type compression apparatus comprising a pressure accumulator vessel storing compressed air, a piston mechanism installed in this vessel and reciprocating by alternating current, an air pump taking in air from outside of said pressure accumulator vessel and delivering compressed air from a discharge port by reciprocation of this piston mechanism, and a drive circuit for supplying alternating current to said piston mechanism, wherein said alternating current is provided with suitable quiescent periods when switching from positive to negative and negative to positive.

[Detailed Description of the Invention]

The present invention relates to an electrically actuated oscillation-type compression apparatus used as a pneumatic power source, for example, for height adjustment of a vehicle, and particularly improved by being configured compactly.

In conventional oscillation-type compression

apparatuses, a time delay caused by the action of inertia and the like of a mechanical system causes oscillations of the mechanical system and an electrical system to mismatch, and efficient actuation was difficult. Figure 1 and Figure 2 show the relationship between piston amplitude, input voltage and input current of a sine wave and a square wave. The electrical system receives electromagnetic force in the intake direction when input current is positive and in the discharge direction when the input current is negative. That is, in the parts of Figures 1 and 2 indicated by hatching, since electromagnetic force acts in the opposite direction of the direction of piston motion, the amplitude and discharge quantity of the piston unfortunately decrease, and this is inefficient. A represents the intake stroke, B represents the discharge stroke,  $i$  represents the intake side,  $r_0$  represents the equilibrium point, and  $h_a$  represents the discharge side.

Therefore, with the foregoing problem in view, an object of the present invention is to provide a highly efficient oscillation-type air compressor by reducing the mismatch of

oscillation between the mechanical system and the electrical system

In order to attain this objective, by the present invention, quiescent periods are provided to the voltage applied to the electrical system, and the length of the quiescent periods when the applied voltage changes from positive to negative and from negative to positive can each be set appropriately.

Next, an embodiment of a case where the present invention is used as a pneumatic power source for height adjustment of a vehicle will be described based on the drawings.

Figure 3 shows a sectional structure of compression apparatus 10 comprising a compressor. Casings 12, 13 are provided tightly sealed above and below cylindrical sleeve 11, forming accumulator vessel 14. Compressor main body 15 is provided inside of this accumulator vessel 14, and this main body 15 is supported in container 14 by support springs 16, 17.

Compressor main body 15 comprises sleeve 18 comprising

a ferromagnetic body arranged coaxially with sleeve 11, and upper cylinder 19 and lower cylinder 20 are each fixed on the inside of both ends of this sleeve 18. These upper and lower cylinders 19 and 20 are arranged coaxially, piston 21 is inserted,

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and cylinders 19, 20 are communicated by container path 22 formed in the center axis of this piston 21.

Discharge valve 23 is provided in upper cylinder 19 and is set to always close the opening port facing piston 21 by spring 25 interposed between this discharge valve 23 and retainer 24 provided to the outside opening port of cylinder 19, and forms the compression air chamber between this valve 23 and retainer 24. Also, this air chamber communicates with retainer 24, and passing through above-mentioned casing 12, communicates with discharge tube 26 extending to the outside of accumulator vessel 14.

Furthermore, bottom lower cylinder 20 communicates with intake tube 27 passing through lower casing cylinder 13 and

extending to the outside of intake tube 27. Check valve mechanism 28 is provided and is configured so that only intake air is introduced to lower cylinder 20.

A brim-shaped flange 29 is provided in the part positioned between upper cylinder 19 and lower cylinder 20 of piston 21. This flange 29 is integrally joined to cylindrical stay 30 installed on the outside of upper cylinder 19, and moving coils 31, 32 are mounted lined up parallel to the axial line on the outside of this stay 30. Here, stator core 33 is provided on the periphery of upper cylinder 19 corresponding to moving coils 31, 32, and furthermore, annular permanent magnets 34, 35 are provided on the inner surface of ferromagnetic sleeve 18 facing this stator 33. These permanent magnets 34, 35 are polarized in a radial direction and set so that their polarities are mutually opposite. In addition, the coil directions of moving coils 31, 32 are also oppositely set and mutually connected.

Furthermore, this piston 21 is supported having free oscillation in the axial direction by springs 26, 27 using

flange 29 between lower and upper cylinders 19, 20.

Exciting current of moving coils 31, 32 is provided from terminals 38a, 38b. Terminal 38a is connected to coils 31, 32 through conductor wire 39, conductive plate material 40, spring 37 and conductive plate material 41, and terminal 38b is connected to coils 31, 32 through conductor wire 42, conductive plate material 43, spring 36 and conductive plate material 44. In the figure, 45 is a communicating tube configured penetrating upper casing 12, and 46 is a pressure sensor detecting pressure in accumulator vessel 14.

Figure 4 shows the total structure of the compression apparatus using above-mentioned compressor 10. Intake tube 27 is joined to air purifier 47, and air cleaned by this air purifier 47 is used as compressed air. Also, discharge tube 26 is communicated with air drier 50 through pipeline 49 of air passage switch circuit 48, and output pipeline 51 from this air drier 50 is joined to communicating tube 45 of compressor 10 through check valve 52 of air passage switch circuit 48. Above-mentioned pipeline 49 branches further



through check valve 53 and provides a source of compressed air for actuation to actuator 54 actuating, for example, a vehicle height adjustment apparatus. Also, communicating tube 45 is connected to this actuator 54 through on-off valve 55. 56 is a valve for exhaust.

Figure 5 shows a drive circuit providing exciting actuation current to moving coils 31, 32 of compressor 10. When pressure sensor 46 detects that the pressure in accumulator vessel 14 is below a specified set pressure, a pulse signal is oscillated from an oscillation circuit (not shown in the figure) receiving the signal of pressure sensor 46. This pulse signal is input to binary counter 47, the counter is advanced once whenever a pulse signal is entered, and the corresponding address signal is output to ROM 48 and quiescent period setting circuit 51. Here binary counter 47 is an  $n$ -bit counter, and if the oscillation-type air compression apparatus is actuated at an electric source frequency  $f$  (Hz), the signal input to binary counter 47, that is, the pulse frequency of point A in the figure will be  $2^n f$  (Hz).

In above-mentioned ROM48, a binary signal corresponding to a square wave is recorded, an address signal is received from binary counter 47, and a square-wave binary signal recorded to an address identical to this address is output to digital-analog converter 49.

The binary signal from ROM48 is converted to an analog signal by digital-analog converter 49, and the converted analog signal is level-converted by difference amplifier 50. The level-converted signal, that is, the signal of point B in the drawing, branches into two, one supplied to NOR circuit 59 and the other

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supplied to through inverter 58 to NOR circuit 80. Also, the relationship between the address signal output from binary counter 49 and the waveform output from difference amplifier 50 is as shown in Figure 6. For example, when quiescent period setting circuit 51 sets the intervals from address 0 to address  $K(0 \leq K \leq N)$  and from address  $N+1$  to address  $P(N \leq P \leq Z)$  as quiescent periods, the address signal output from the address

corresponding to these quiescent periods and the signal output from binary counter 47 are constantly compared. Also, while the address signal of the address corresponding to the voltage impression quiescent period is detected, quiescent period setting circuit 51 outputs the signal to above-mentioned NOR circuits 59 and 60.

A NOR signal of a signal output by difference amplifier 50 and a signal output by quiescent period setting circuit 51 is output by NOR circuit 59, and this signal controls the ON-OFF of transistors 54, 57. Also, A NOR signal signal of a signal output by difference amplifier 50 and passing through inverter 58 and a signal taking output from quiescent period setting circuit 51 is output by NOR circuit 60, and this signal controls the ON-OFF of transistors 55, 56. Furthermore, a voltage of a waveform having quiescent periods  $t_1$ ,  $t_2$  as shown in Figure 7 is output from these transistors 54, 55, 56, 57 to moving coils 31, 32. (i: intake side, ro: discharge side).

The waveforms of the signals in points A, B, C, D, E, F in Figure 5 are as shown in Figure 8.

Next, from the experimental results, the effect of square-wave actuation of the present embodiment will be described compared to that of a conventional apparatus.

The uniform flow rate diagram shown in Figure 9 indicates measurement results when constant electric power is supplied to the oscillation-type air compressor apparatus of the present embodiment, the discharge gauge pressure is  $8 \text{ kg/cm}^3$  and the time ratio ( $t_2/T_1$ ,  $t_1/T_2$ , wherein  $T_1=T_2$ ) of voltage quiescent periods is varied. In the present embodiment, voltage impression quiescent period  $t_1$ ,  $t_2$  can be determined suitably by suitably setting the address corresponding to the quiescent period of quiescent period setting circuit 51.

In conventional oscillation-type air compression apparatuses, since  $t_1/T_1=t_2/T_2$ , the flow rate above straight line (X) in Figure 8 is all that can be obtained. Therefore, in order to obtain a flow rate greater than in conventional apparatuses,  $t_1/T_1=t_2/T_2$  can be set in the region indicated with diagonal lines Y, and in particular, if set to  $t_1/T_1=0.2-0.4$ ,  $t_2/T_2=0.5-0.65$ , optimum flow rate can be

obtained.

Furthermore, piston oscillation, input voltage waveform, and input current waveform when quiescent period rate is set to  $t_1/T_1=0.3$ ,  $t_2/T_2=0.5$  and a square wave is impressed is shown in Figure 10. As can be seen in the figure, the hatched part generating electromagnetic force in a direction opposite the direction of piston motion decreases compared to in conventional apparatuses, showing that actuation is highly efficient.

As explained above, if the oscillation-type air compression apparatus of the present invention is used, the mismatch between oscillation of the mechanical and electrical systems can be decreased, and efficient compression can be achieved.

#### [Brief Description of the Drawings]

Figure 1 and Figure 2 show the relationship between piston oscillation, input voltage and input current of a conventional oscillation-type air compression apparatus. Figures 3-9 relate to the embodiment of the present invention,

wherein Figure 3 is a longitudinal sectional view of the compressor; Figure 4 is an overall block diagram; Figure 5 shows the drive circuit; Figure 6 shows the relationship between the address signal output from the binary counter and the square waveform output by the difference amplifier; Figure 7 shows the input waveform input to the moving coil; Figure 8 shows the signal at a point in Figure 5; Figure 9 is a uniform flow diagram; Figure 10 shows the relationship between piston oscillation, input voltage, and input current.

- 10 ..... Compressor
- 14 ..... Accumulator vessel
- 15 ..... Compressor main body
- 16, 17 ..... Support springs
- 19 ..... Upper cylinder
- 20 ..... Lower cylinder
- 21 ..... Piston
- 22 ..... Air passage
- 26 ..... discharge tube
- 27 ..... discharge tube

31, 32 ..... Moving coils  
33 ..... Stator core  
34, 35 ..... Permanent magnet  
45 ..... Communicating tube  
46 ..... Pressure switch  
100 ..... Drive circuit

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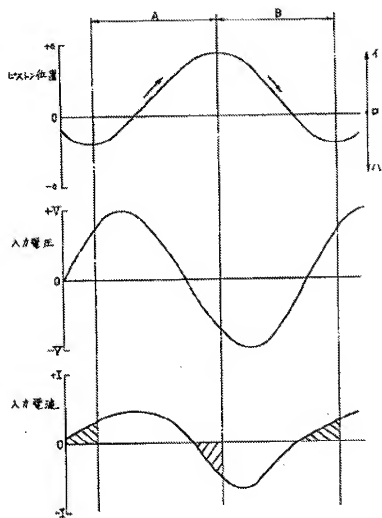
[Ammendment]

Rewrite item of "1 [Scope of Patent Claims]" as

"An oscillation-type air compression apparatus comprising a pressure accumulator vessel storing compressed air, a piston mechanism installed in this container and reciprocated by alternating current, an air pressure pump taking in air from outside of said pressure accumulator and sending compressed air from a discharge port by reciprocation of this piston mechanism, and a drive circuit for providing alternating current to said piston mechanism, wherein said alternating current switches between positive and negative in an intake step and a discharge step of said piston mechanism, and when said alternating current switches from positive to negative and negative to positive, each suitable and mutually different quiescent period is provided to the alternating current, and the quiescent period of the intake period is longer than that of the discharge period."

Figure 1





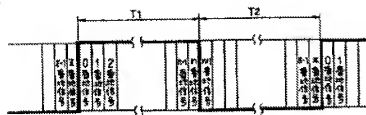
From top to bottom:

Piston position

Input voltage

Input current

Figure 6



From left to right:

z-1 address signal

z address signal

0 address signal

1 address signal

2 address signal

n-1 address signal

n address signal

n+1 address signal

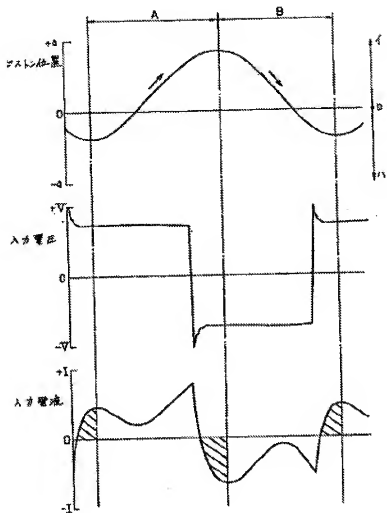
x-1 address signal

x address signal

0 address signal

1 address signal

Figure 2



From top to bottom:

Piston position

Input voltage

Input current

Figure 3

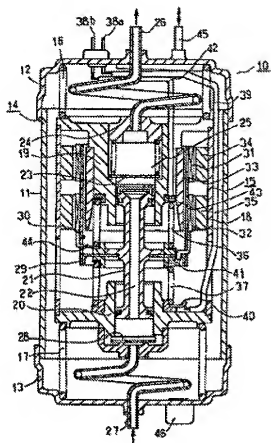


Figure 4

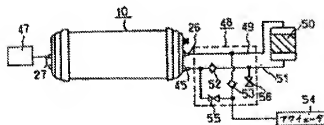


Figure 5

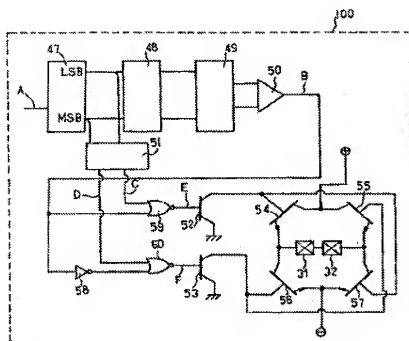
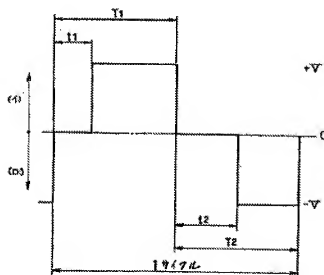


Figure 7



From top to bottom:

(i)

(ro)

From left to right:

1 cycle

Figure 8

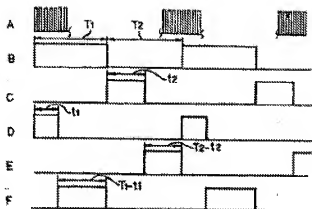
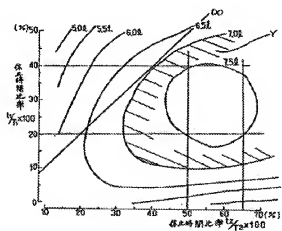


Figure 9



Vertical axis: Quiescent period rate  $(t1/T1) \times 100$

Horizontal axis: Quiescent period rate  $(t_2/T_2) \times 100$

Fig.10

